Faculty of Manufacturing Engineering

SURFACE ROUGHNESS STUDY ON MILD STEEL IN HIGH SPEED TURNING PROCESS

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Master of Manufacturing Engineering
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MUHAMMAD KAMAL ASYRAF BIN PUBIN

A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)

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DEDICATION

To the many people who encouraged me to grow professionally and spiritually over the years, especially my wife, Nurulhusna, my beloved parents Hajjah Umi Kalsom and Haji Pubin, my lovely daughter and sons, Aisyah Amanina, Adam Muhammad, Afham Muhammad and my inspirited siblings. Included also are a great many fellow educators, students, and peoples that I am indebted to.

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ABSTRACT

Surface integrity was the surface condition of a workpiece after being modified by a manufacturing process and it can change the material's properties. In surface topography, surface roughness (Ra) was concerned with the geometry of the outermost layer of the workpiece texture and the interface exposed with the environment affects several functional attributes of parts, such as friction, wear and tear, light reflection, heat transmission, ability of distributing and holding a lubricant, coating etc. Therefore, the desired surface finish was usually specified and appropriate processes were required to assess and maintain the quality of a component. The research was to investigate the influence of machining parameters and optimum process parameter to the surface roughness value of mild steel material in high speed turning using chemical vapor deposition (CVD) coated carbide insert in dry condition. Two level factorial design of experiment were selected to arrange the cutting parameters of cutting speed with range of 270 to 450m/min and the feed rate with 0.1 to 0.3mm/rev.The values were recorded for each 1.6mm constant depth of cut until flank wear (Vb) reached 0.2mm on the insert. From the experimental results, high cutting speed significantly produced fine surface roughness and high feed rate resulted to a rougher surface roughness. Optimizations of parameters show that cutting speed with 450m/min and feed rate of 0.1mm/rev obtain a minimum surface roughness of 1.31μm.The mathematical modeling analysis for the surface roughness (Ra) on mild steel equal to $0.545 - 6.835 \times 10^{-4}$ * Cutting Speed + 10.695 * Feed Rate.

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ABSTRAK

*Integriti permukaan adalah keadaan permukaan bahan kerja selepas diubah suai oleh proses pembuatan dan ia boleh mengubah sifat sesuatu bahan. Di dalam permukaan topografi, kekasaran permukaan (Ra) dikaitkan dengan geometri tekstur dan antara muka lapisan paling luar bahan kerja yang terdedah kepada keadaan persekitaran dan akan memberi kesan kepada sifat-sifat fungsi bahagian seperti geseran, haus dan lusuh, pantulan cahaya, penghantaran haba, keupayaan mengedarkan dan memegang pelincir, salutan dan lain-lain. Dengan itu, kemasan permukaan yang dikehendaki biasanya ditetapkan dan proses yang sesuai diperlukan untuk mengekalkan dan menentukan kualiti komponen. Kajian ini adalah untuk mengkaji kesan parameter pemesinan larik berkelajuan tinggi ke atas nilai kekasaran permukaan dan mementukan parameter pemesinan optimum pada bahan keluli lembut menggunakan mata alat karbida CVD dalam keadaan kering. Rekabentuk ekperimen dua tahap faktorial telah dipilih untuk menghasilkan parameter kelajuan pemotongan dengan pelbagai kelajuan bermula dari kelajuan 270m/min hingga 450m/min serta dengan kadar suapan dari 0.1mm/rev hingga 0.3mm/rev. Pada setiap 1.6mm kedalaman pemotongan, nilai haus rusuk(Vb) dicatatkan sehingga mencapai nilai 0.2mm pada mata alat. Berdasarkan keputusan eksperimen, pemotongan larik pada kelajuan tinggi menghasilkan kekasaran permukaan halus dengan ketara dan kadar suapan yang tinggi menghasilkan permukaan yang lebih kasar. Melalui proses pengoptimuman parameter menunjukkan bahawa pemotongan dengan kadar kelajuan 450m/min dan kadar suapan 0.1mm/rev akan menghasilkan nilai kekasaran permukaan yang minimum iaitu 1.31µm. Model matematik yang dijana daripada analisis kekasaran permukaan (Ra) pada keluli lembut bersamaan dengan +0.54509 - 6.834x10^{-4} * Kelajuan Pemotongan + 10.695 * Kadar Suapan.*

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"Bismillahirrahmanirrahim"

"In the name of Allah, The Most Beneficent, The Most Merciful"

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CHAPTER 1

INTRODUCTION

This chapter explains the introduction of the research on "Surface Roughness Study on Mild Steel in High Speed Turning Process". In extension, this chapter will elaborate on the problem statement, objectives and scopes of the research.

1.1 Project Background

The global manufacturing sector has undergone a tumultuous decade with large developing economies leaped into the first tier of manufacturing nations. Manufacturing industries in this modern era remains a critical force in both advanced and developing economies. As the end of the twentieth century approached, manufacturing industries faced new technology in many areas. In the latter, it remains a vital source of innovation and competitiveness, making outsized contributions to research and development.

Surface integrity is one of the fast developed technologies and become the main interest field of study especially in an industry. A surface engineering technology which deals with the surface of solid matter that was interacts with the surrounding environment. The surface integrity of a workpiece or item changes the material's properties and can have a great impact on a parts function (Michael Field, 1964). This research will discuss entirely on the surface integrity in surface roughness via surface layer characteristics in improving the quality of the surface roughness value, Ra. The surface layer characteristics that can change through processing such as plastic deformation, residual stresses, cracks, hardness, overaging, phase changes, recrystallization, intergranular attack, and hydrogen embrittlement.

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When a traditional manufacturing process such a turning is used, the surface layer sustains local plastic deformation. Traditional processes involve the tool contacts with the workpiece surface. These processes will only damage the surface integrity if the improper parameters are used, such as dull tools, too high feed speeds, improper coolant or lubrication, or incorrect grinding wheel hardness. Turning operation is the machining operation in which a single-point cutting tools removes material from the surface of a rotating cylindrical part. The cutting tool is fed linearly in a direction parallel to the axis of rotation. In turning, the parameters condition of cutting speed, feed rate and depth of cut are need to be selected properly in order to optimize the turning operation.

Another aspect that needs to be considered in affecting the surface integrity of material is the material to be machined. In most industrial common application, mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel has allowed carbon content (up to 0.3%) and is therefore neither extremely brittle nor ductile. It becomes malleable when heated, and so can be forged. It is also often used where large amounts of steel need to be formed, for example as structural steel. Mild steel material is widely used in basically the most common industrial products, such as bolts, nuts, sheet, plate, and tubes, and for machine components that do not require high strength. This includes motorcycle frames, automobile chassis, cookware and etc. But due to peculiar characteristics such suffer from yield-point runout and has a relatively low tensile strength (Degarmo, 2003). It is, highly susceptible to corrosion (rusting) when exposed to moisture and has several typical problems which usually can be identified by visual inspection. Good surfaces machining with generation of smooth surface on the mild steel components during turning operation is a challenge to the manufacturing engineers in practice.

1.2 Problem Statement

The manufacturing process of material and the specification or enhanced surfaces require an understanding of the interrelationship among metallurgy, machinability and mechanical testing. To satisfy this requirement, an encompassing discipline known as surface integrity was introduced and it has gained worldwide acceptance. Surface integrity is the surface condition of a workpiece after being modified by a manufacturing process. The surface integrity of a workpiece or item changes the material's properties and can have a great

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impact on a parts function and is very important for the components adapting to high thermal and mechanical loads during their applications (Axinte, Dewes and Twardowski, 2011). Surface integrity technology describes and controls the many possible alterations produced in a surface layer during manufacture, including their effects on material properties and the performance of the surface in service. Surface integrity is achieved by the selection and control of manufacturing processes, estimating their effects on the significant engineering properties of work materials, such as fatigue performance. Surface roughness is one of the various properties of an engineering surface that affect the performance of this surface in service (Davim, 2010). Surface roughness also affects several functional attributes of parts, such as friction, wear and tear, light reflection, heat transmission, ability of distributing and holding a lubricant, coating etc. Therefore, the desired surface finish is usually specified and appropriate processes are required to maintain the quality (Bhushan, 1999). Hence, the inspection of surface roughness of the work piece is very important to assess the quality of a component. To ensure better and finer surface roughness, special attention must be paid in selection of workpieces material, cutting parameters, tool material and geometry and tool coatings (Krolezky,Nieslony and Stoic 2013). The effect of machining parameters on the surface integrity in the context of surface roughness characteristics /quality of the machined part is very important in order to understand the relationship between machining parameters and finer surface roughness value.

1.3 Objectives

The objectives of the research are;

1. To investigate the influence of machining parameters to the surface roughness value, Ra during high speed turning of mild steel material under dry condition.
2. To define optimum process parameter setting to minimize surface roughness value, Ra of mild steel.
3. To develop mathematical model for surface roughness of machined surface.

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1.4 Project Scope

The scope of the research focuses on the surface integrity (surface roughness) on sub-surfaces of machined mild steel material grades JIS G3101 SS400 during high speed turning with dry cutting condition. The surface roughness variations in single point turning operation are investigated at different cutting speed and feed rate. The machining parameters evaluated are feed rate, cutting speed and depth of cut. The depth of cut will be constant value mean while the cutting speed and feed rate are will be manipulate. The value of the parameters and types of cutting tool are discussed in Chapter 3.

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CHAPTER 2

LITERATURE REVIEW

This chapter consists of the information gathered regarding to the project title which is surface roughness study on mild steel material in high speed turning. Every aspect that will be involved in this research will be discussed and elaborated extensively by the guidance of prior research by the previous researcher. The review covers about workpiece material (mild steel), turning operation, cutting condition (dry condition), cutting tool, tool wear, surface roughness and the design of experiments of methods.

2.1 Mild Steel Material

Mild steel or known as low carbon steel which is an AISI grades 1005 through 1025 is one of the important carbon steel among all carbon based steel. Mild steel, also known as low carbon steel is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. It contains only a small percentage of carbon (low carbon steel) and is strong and easily worked but not readily tempered or hardened. Normally the iron-carbon alloy containing less than 0.25 percent carbon which makes it more ductile and less hard thus, rendering it unsuitable for structural work (Knowles and Peter Reginald, 1987). Mild steel has allowed carbon content (up to 0.3%) and therefore, neither extremely brittle nor ductile. It becomes malleable when heated, and so can be forged. It is also often used where large amounts of steel need to be formed, for example as structural steel and is widely used in basically the most common industrial products, such as bolts, nuts, sheet, plate, and tubes, and for machine components that do not require high strength. This includes motorcycle frames, automobile chassis, cookware and etc. Due to peculiar characteristics such a suffer from yield-point runout and has a relatively low tensile strength (Degarmo, 2003), it is highly susceptible to corrosion (rusting) when exposed to moisture and has several typical problems which usually can be identified by visual inspection.

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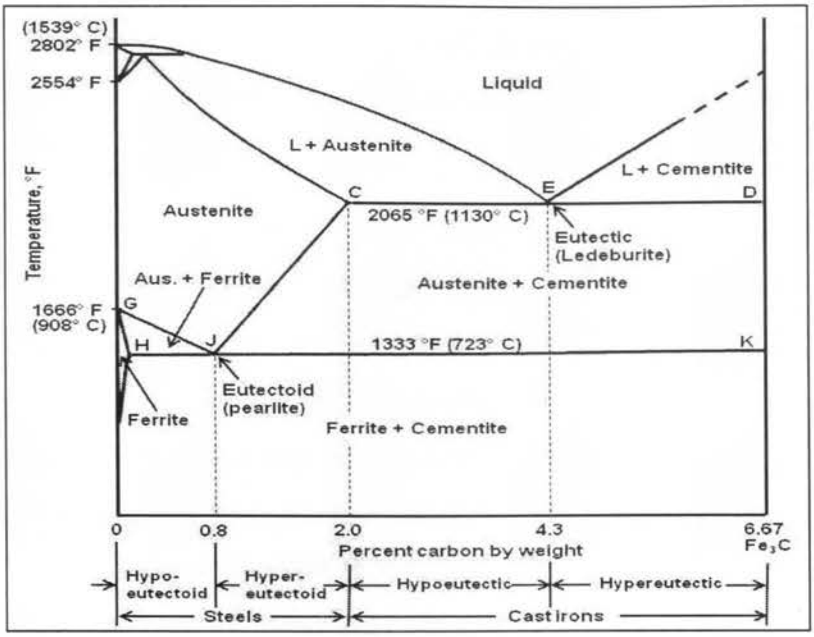

Figure 2.1: The iron carbide equilibrium diagram (Shah, 2009)

Mild steel has a relatively low tensile strength, but it is cheap and easy to form, the surface hardness can be increased through carburizing. It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) (Elert and Glenn, 2009) and the Young's modulus is 210 GPa (30,000,000 psi). The tensile strength is a maximum of 500 MPa (72500 psi). In mild steel, the carbon is the primary alloying element, with the level of carbon contained in steel being one of the most important factors governing its mechanical properties. Mild steel has no more than 1.65% manganese, 0.6% silicon or 0.6% copper. Mild steel is available with varying levels of formability. The more formable grades are typically more costly than the less formable grades.

2.2 Turning Process

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, workpiece, fixture, and cutting tool. The workpiece is rotated on a spindle and the tool is fed into it radially, axially or both ways simultaneously to give the

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required surface finish (George Schneider Jr, 2010). The cutter is typically a single-point cutting tool that is also secured in the machine, although a cutting process can possibly be completed with a single pass or it may require multiple passes (Yi-Chi Wang *et al.*, 2010). The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.

Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

Turning machines are additionally ready to be computer controlled and known as a computer numerical control (CNC) lathe machine. The common cutting tool utilized as a part of the CNC machine has a replaceable cutting edge (tool insert). CNC machines pivot the work-piece and move the cutting tool established by the commands that are prearranged and precise. In this diverse type of turning machines, the principle parts that empower the work-piece to be turned and the cutting tool to be subjected to the workpiece remains unchanged. Figure 2.2 shows the basic concept of turning operation.

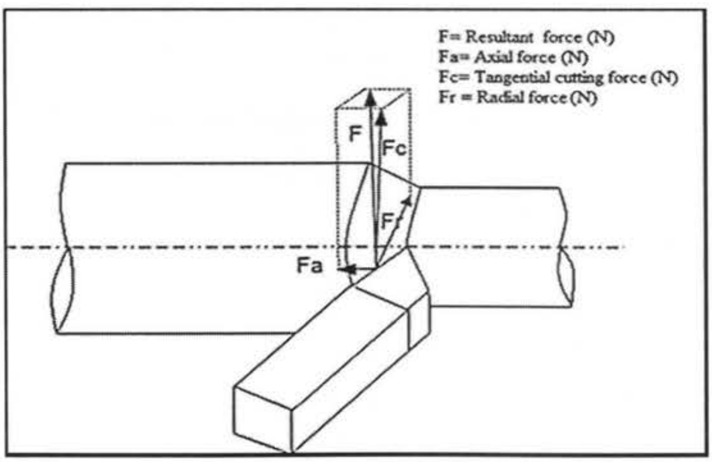

Figure 2.2: Basic concept turning operation (Kalyan and Samuel, 2014)

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2.2.1 Types of Turning Operation

There are few types of turning operation that need specific types of tools for the operation to performed in most productive way. Figure 2.3 shows the types of tools for specific turning operation (Chiles *et al.*,1996).

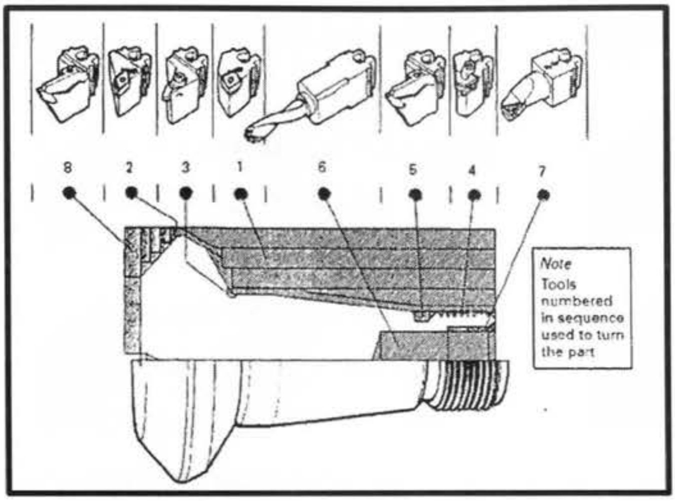

Figure 2.3: Types of tools for turning operation

1: Rough Turning	5: Recess Turning
2: Profile Turning	6: Drilling
3: Groove Turning	7: Boring
4: Thread Turning	8: Profile turning and Parting off

2.3 Cutting Parameters

In turning process, the most important cutting parameters are cutting speed (v), feed rate (f), and depth of cut (d). Cutting speed is the speed of the workpiece material measured in meters per minute. Feed is the rate which the cutting tool is traveling in millimeters per each spindle revolution. The depth of cut is the amount of material removed from the workpiece measured in millimeters. The selection of these parameters influences cutting

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forces, power consumption, surface roughness of the workpiece and cutting tool life. Cutting parameters are usually selected based on the workpiece, tool material, and tool geometry (Trent and Wright, 2000). The selection of these cutting parameters affects the metal cutting processes (Krishan Prasad, 2013).

2.3.1 Cutting Speed (*v*)

Cutting speed is the speed difference (relative velocity) between the cutting tool and the surface of the workpiece it is operating in turning operation. It is expressed in units of distance along the workpiece surface per unit of time, typically surface feet per minute (sfm) or meters per minute (m/min) (Smid, 2008). For example as in a turning operation, a cutting speed for mild steel, of 100 ft/min (or approx 30 meters/min) is the speed of the (stationary) cutter passing over the (moving) workpiece. Speed at the workpiece surface can be thought of as the tangential speed at the tool-cutter interface, that is, how fast the material moves past the cutting edge of the tool. In turning operation, the surface can be defined on either side of the depth of cut, that is, either the starting surface or the ending surface, with neither definition being "wrong" as long as the people involved understand the difference (Gosselin and Jim, 2016). The logic of focusing on the largest diameter involved is that this is where the highest tangential speed is, with the most heat generation, which is the main driver of tool wear. For a given material there will be an optimum cutting speed for a certain set of machining conditions, and from this speed the spindle speed (RPM) can be calculated. Factors affecting the calculation of cutting speed are:

- The material being machined
- The material the cutter is made from
- The economical life of the cutter

Equation 2.1 shows formula of cutting speed between diameter of workpiece and spindle speed. Factors affecting the calculation of cutting speed are (Kalpakjian, 2006):

$$V = \pi \times D \times Ns \qquad (2.1)$$

Where, V = Cutting speed (m/min)
D = Diameter of material (mm)
Ns = Spindle speed (RPM)

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The cutting speed is given as a set of constants that are available from the material manufacturer or supplier, the most common materials are available in reference books, or charts but will always be subject to adjustment depending on the cutting conditions. The following table gives the cutting speeds for a selection of common materials under one set of conditions. The conditions are a tool life of 1 hour, dry cutting (no coolant) and at medium feeds. According to Kundrak et al. 2011, turning performed at high speed is an intensive technology in terms of the heat generated in the process. The temperature of the workpiece material in the cutting edge area may reach the transformation temperature.

Table 2.1: Cutting speeds for various materials using a plain high speed steel cutter (Brown & Sharpe 1995)

Material type	Meters per min (MPM)	Surface feet per min (SFM)
Steel (tough)	15–18	50–60
Mild steel	30–38	100–125
Cast iron (medium)	18–24	60–80
Alloy steels (1320–9262)	20–37	65–120
Carbon steels (C1008–C1095)	21–40	70–130
Free cutting steels (B1111–B1113 & C1108–C1213)	35–69	115–225
Stainless steels (300 & 400 series)	23–40	75–130
Bronzes	24–45	80–150
Leaded steel (Leadloy 12L14)	91	300
Aluminium	75–105	250–350
Brass	90–210	300–700 (Max. spindle speed)

2.3.2 Feed Rate (*f*)

Feed rate is the relative velocity at which the cutter is advanced along the workpiece, its vector is perpendicular to the vector of cutting speed. Feed rate units depend on the motion of the tool and workpiece. When the workpiece rotate in turning operation, the units are almost always distance per spindle revolution (inches per revolution [in/rev or ipr] or millimeters per revolution [mm/rev])(Smid ,2008). Feed rate is dependent on the:

- Type of tool surface finish desired.
- Power available at the spindle (to prevent stalling of the cutter or workpiece).

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